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CREW CHIEF: A MODEL OF A MAINTENANCE TECHNICIAN

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CREW CHIEF is a 3-dimensional computer-aided design (CAD) model of a military maintenance technician. The model is interfaced to existing commercial CAD systems used by aerospace manufacturers. CREW CHIEF enables designers to identify maintainability problems early in the weapon system design process by analyzing the interaction between the maintenance technicians' physical capabilities and the design requirements related to specific tasks.

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CREW CHIEF: A MODEL OF A MAINTENANCE TECHNICIAN

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SUMMARY

CREW CHIEF is an interactive human factors evaluation tool that interfaces to commercially available computer-aided design (CAD) systems. The three-dimensional modeling system creates a computerized man-model representing a range of body sizes of both male and female Air Force maintenance technicians. The user may place the CREW CHIEF model into a design drawing and run an analysis of the interaction between the man-model's physical capabilities and the design elements related to a specific task. CREW CHIEF's data base includes information for modeling the encumbrance of clothing and personal protective equipment, physical access limitations for reaching into confined areas, visual access, and strength capabilities.

PREFACE

The information in this paper was presented at the AIAA/NASA Symposium on the Maintainability of Aerospace Systems, on 26-27 July 1989 in Anaheim, California. This work was performed under Work Unit 17100028.

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I. INTRODUCTION

Thirty-five percent of a weapon system's life-cycle cost is spent on maintenance and the equipment and personnel to support it (McDaniel & Askren, 1985). One third of all Air Force enlisted personnel perform maintenance-related activities. The high cost of maintenance is due, in part, to poor design. Much of this cost could be avoided if, during the system's preliminary design stage, the interaction between the maintenance technician and the system design could be analyzed.

Some factors contributing to design related maintainability problems include:

1. lack of feedback to the designer on previous maintainability problems.

2. lack of three-dimensional representations of the assemblies so the designer can visualize and analyze accessibility for maintenance tasks.

3. the designer's lack of experience with ergonomics problems, statistics, and interacting variables.

4. lack of applicable ergonomics data in a format the designer can use and understand.

In order to detect possible problems early in the design process, the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL) and the Air Force Human Resources Laboratory (AFHRL), in conjunction with the University of Dayton Research Institute (UDRI), have developed a computer-aided design (CAD) model of an aircraft maintenance technician, called CREW CHIEF. This model addresses factor (4) above, and is intended to eliminate design-induced maintainability problems by providing a realistic simulation of a maintenance technician to the system designer.

II. THE PROGRAM

CREW CHIEF is an interactive, three-dimensional model which is interfaced to existing commercial CAD systems. This model and its supporting data base provide a designer with a computer simulation of a maintenance technician, allowing early identification of maintainability problems and reducing the requirement for a full scale mock-up. The designer may place CREW CHIEF into his drawing and analyze the interaction between the model's physical capabilities and the design elements related to a specific maintenance task.

The Data Base

Because the CREW CHIEF model is a simulation of the physical characteristics and limitations of the maintenance technician, an extensive data base has been developed to support it. The data base for the model was created from ergonomics studies specifically designed to simulate aircraft maintenance tasks. For example, strength data from test subjects were related to the aircraft technician population through a series of strength tests that had been previously administered to Air Force personnel. Since there are few restrictions on the assignment of Air Force personnel to their jobs categories, these subjects were determined to be representative of the Air Force maintenance technician population. During the data collection phase of the Torque and Materials Handling data base, subjects performed one to seven of the same strength tests. Regressors from the data collection were used to distribute the predictions from the Torque and Materials data base across the maintenance population.

The data base also contains 105 different sizes and types of hand tools commonly used in aircraft maintenance. Evaluations using the tools include accessibility (reach, interference, work envelope, and visibility) and strength (torque).

The Man Model

Body size/gender, clothing encumbrance, and posture must be considered for each area of maintainability. The CREW CHIEF program can accommodate one of ten body size/gender combinations (1st, 5th, 50th, 95th, and 99th percentile for both male and female maintenance technicians) based on military standards.

The encumbrance of clothing and Personal Protective Equipment (PPE) is an important limitation for the maintenance technician. A designer has four types of standard clothing to choose from: fatigues, fatigues with jacket, arctic gear, or the chemical defense ensemble. These clothing interact with the joint mobility limits and postures to model accessibility.

Because the CREW CHIEF model is three dimensional, it has a surface of facets (triangles) attached to the 35 links comprising the skeletal link system. A simplified 3-D model is available for rotating the model, while a hidden line 2-D model can be used for high-resolution views and plots.

To simulate the postures typical in maintenance, the CREW CHIEF program provides for 12 initial postures: standing, sitting, kneeling on one knee, kneeling on both knees, bending, squatting, prone, supine, lying on one side, walking, crawling, and climbing. Some of these postures reduce the mobility and strength available to perform a maintenance task. The designer can manipulate all the body segments, within limits, to get the desired posture.

III. ANALYSIS FACILITIES

Maintainability problems generally fall into three areas: physical accessibility, strength, and visibility. Physical accessibility is affected by body size, posture, tool size, adjacent or interfering components, and the task performed (such as lift, push, pull, or reach). Strength involves the technician's physical ability (which is a function of gender, posture, and task performed) to apply a specified torque, and/or to lift, position,

carry, or remove an object. Visibility is the technician's field of view relative to his/her posture, location of the object, and components which may obscure the work area. The functions within the CREW CHIEF system of programs allow the user to analyze these maintainability problems as described below.

Accessibility Analysis

The Accessibility Analysis function is provided to perform analyses concerning interference between elements of the CREW CHIEF model and elements of the CAD drawing depicting the location of work. The function is divided into two areas: Interference Analysis and Work Envelope Analysis. Interference Analysis checks interference between CREW CHIEF and drawing elements in a static condition. Work Envelope Analysis, a quasi-dynamic interference check, presents a graphic display of the volume of space required to operate a tool, or the movement of an object (such as a component to be removed or installed) in the work area.

Maintenance Task Analysis

The Maintenance Task Analysis function is designed to evaluate the interactions of the the CREW CHIEF model and the user's design with respect to certain physical characteristics of the model. The function is separated into three parts: the Tool Analysis function, the Materials Handling function, and the Connector Analysis function.

Tool Analysis

This function evaluates the ability to reach, with a tool and from a designated posture and position, a specified task point (see Figure 1). This includes the ability to reach around obstacles between the model (holding the tool) and the task point. For specified wrenches, once it is determined that the point can be reached, the strength capability for the particular size model, posture, and tool relationship will be displayed. A limited visual analysis of tool clearance may be made when the tool has been positioned.

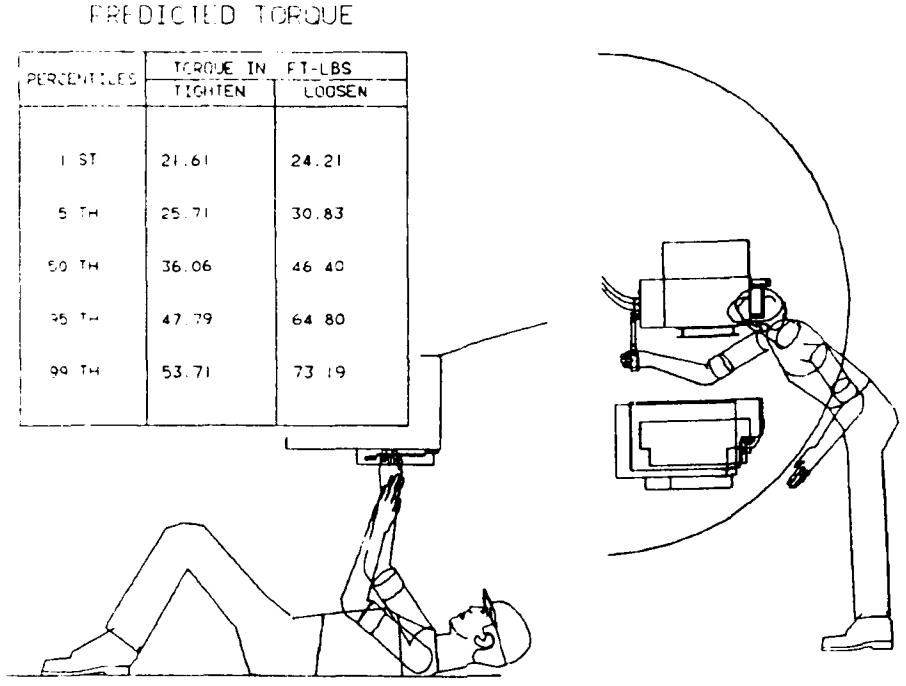
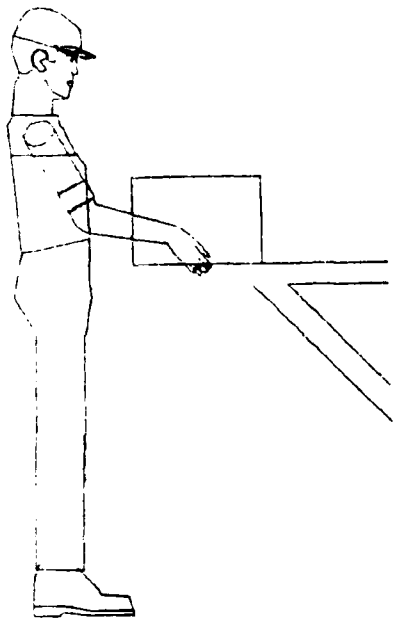


Figure 1. CREW CHIEF Tool Analysis.

Materials Handling Analysis

This function evaluates the capabilities of the maintenance technician to lift, push, pull, turn, hold in position, carry, or reach an object (see Figure 2). In this function, there is also a table displaying the 1st, 5th, 50th, 95th, and 99th percentile strength capabilities for the starting and ending positions and size and weight of the object, all of which are available to complete the task being simulated.



DESIGN WEIGHT LIMITS FOR LIFT

MIL-STD 1472		PREDICTED WEIGHT	
DISTANCE FROM TARGET	WEIGHT LIMITS	PERCENTILES	LBS
<=12 IN	37 LBS	1 ST	78.66
>12 & <=18 IN	24.8 LBS	5 TH	90.47
		50 TH	118.50
>18 & <=24 IN	18.5 LBS	95 TH	161.91
>24 IN	12.6 LBS	99 TH	166.49

Figure 2. CREW CHIEF Task Analysis.

Connector Analysis

The capability of the maintenance technician to attach a connector at a specified location is evaluated with this function. A user will find a table of the strength capability related to grip used and the size of the connector. This table displays the torque applied in inch-pounds across five percentiles (1st, 5th, 50th, 95th, 99th).

Visibility Analysis

A visibility analysis function is available to the designer that plots a map of visual azimuth and elevation line-of-sight angles to work station components in the drawing (see Figure 3). The plot is rectilinear, and depicts the visual field as seen by the CREW CHIEF model in its current posture, or as seen from a user-chosen, arbitrary viewpoint. The vision limits are presented for the baseline condition, which is unrestricted, and for restrictions due to clothing or personal protective equipment.

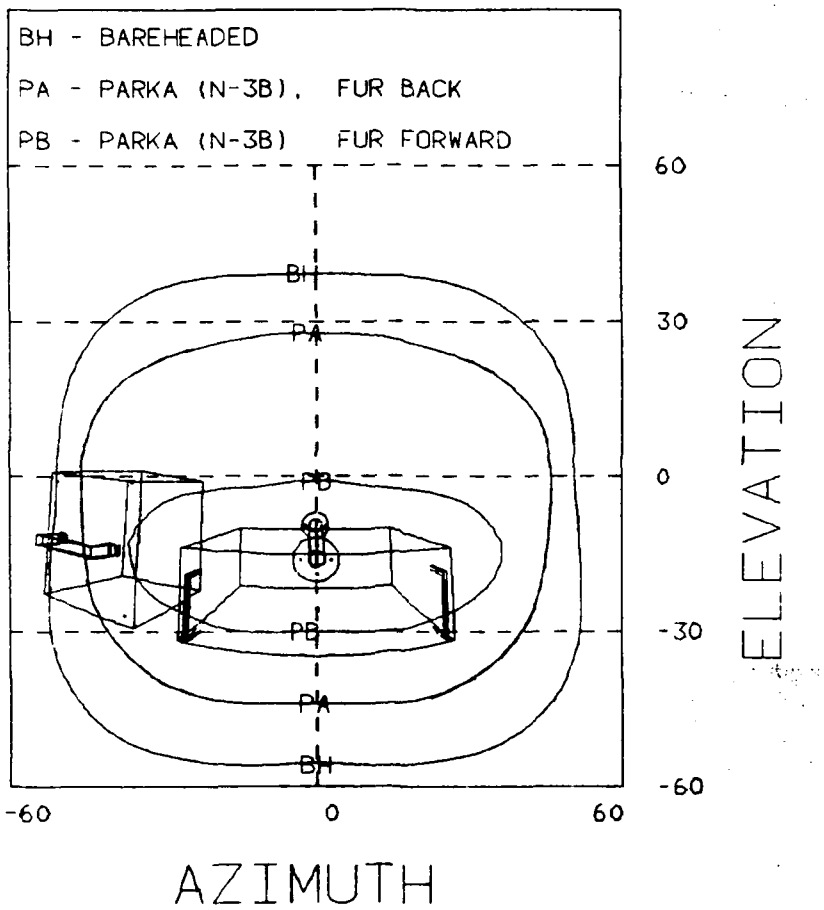


Figure 3. CREW CHIEF Visibility Analysis.

A maintainability problem may involve combinations of these three analyses. For example, lack of visibility may aggravate a physical accessibility problem by making it more difficult to properly align and position a tool in a restricted working area.

IV. SYSTEM INTERFACE

The CREW CHIEF system of programs is designed to interact with several popular CAD software packages and their data bases. Therefore, CREW CHIEF runs on the same hardware used to run the CAD/CAM software. One version of CREW CHIEF runs under CADAM (Computer Aided Design and Manufacturing). CADAM is a registered trademark of CADAM, Inc. of Burbank, California.

Version 20 requires the user to have the 3-D Interactive and Manufacturing and Geometry Interface Module, MVS Operating System, and FORTRAN H (Korna et al., 1988a). A second version of the model executes under the Computervision. Computervision is a registered trademark of Computervision Corporation of Bedford, Mass. CDS 4001 system with an Analytical Processing Unit (APU) and CADDS 4X software, Revision 5B or later (Korna et al., 1988b). Another version of CREW CHIEF is system independent and is designed to be compatible with the operating procedures and terminology of the host system.

The CREW CHIEF system of programs is interfaced directly to the CAD software, and follows very closely the nomenclature and user interface methods employed by the CAD system. Thus minimal training time is required for the experienced CAD user to learn to use the CREW CHIEF program.

V. FUTURE DIRECTIONS

To aid users in designing for quick, easy repair, future versions of CREW CHIEF will provide the designer with task time estimations for removal and replacement of aircraft components. The Task Time Estimator will consider such variables as posture, clothing type, and interference, on aircraft repair time.

The CREW CHIEF system of programs will also be enhanced to accommodate the special needs and restrictions induced by the space environment. For this new system of programs, all configurations of current and planned space clothing will be modeled for each of the 10 body sizes already available with CREW CHIEF. The model will include a space maintenance tools data base for equipment used inside and outside the spacecraft. All space maintenance activities will be included in the model.

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